

Emerging Technologies in Pharmaceutical Industry

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ABSTRACT

In recent years, technology has played an increasingly important role in pharmaceutical industry, transforming the way drugs are discovered, developed, and delivered to patients. Emerging technologies in pharmaceutical industry continue to be a major force behind transformative changes in the healthcare industry. The technologies are being adopted at each stage of a medicine's lifespan. The pharma technologies will not only evolve but revolutionize the way medicines are manufactured, researched, and distributed. Mastering emerging technologies is essential to optimize your organization's performance. This paper reviews the technological trends that will redefine the pharmaceutical sector.

KEYWORDS: *technology, emerging technologies, pharmaceutical industry, pharma*

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INTRODUCTION

The pharmaceutical sector has witnessed a period of accelerating technology adoption due to new ways of working, driven in part by the requirement to manufacture new process modalities, as well as the need to deliver new facilities in a quicker and more cost effective manner. The sector is undergoing a significant transformation, driven by the rapid integration of emerging technologies such as artificial intelligence, additive manufacturing, big data, cloud computing, industrial internet of things, robotics, blockchain, cybersecurity, and wearables. They improve the accuracy, speed and safety and more to do so while being compliant to the correct regulatory standards. This has led to new strategies in sourcing, manufacturing, and supply chain operations.

The world is moving forward with science and technology. Every day new discoveries and researches are taking us one step closer to the future with many wondrous technological trends and advancements. Technological growth has brought a revolution in the pharmaceutical industry [1]. Technology touches every facet of pharmaceutical

operations, from research laboratories to quality assurance and everything in between. Bringing together various technologies can ensure that each stage in drug development is based on diverse, nuanced, and real patient populations. Understanding these new technologies allows industry players to stay resilient in the face of an increasingly challenging landscape, from labor shortages to supply chain disruptions.

In recent years, we have seen breakthroughs in vaccine development, cancer treatments, drug development that are revolutionizing obesity management, gene therapy and gene editing technology for rare diseases and new treatments for complex diseases like Alzheimer's. Yet the sector continues to experience under-performance in capital markets relative to the market index. Reinventing the pharma business model is paramount. Leading companies will likely invest in digital technologies such as AI, data analytics and machine learning to help accelerate the drug development process [2].

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as “emergent.” It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a “must-have” [3]. An emerging technology is the one that holds the promise of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [4]:

- *Novelty*: Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption*: Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty*: Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change*: Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. The military often looks to emerging

technologies for new services or tools that will help them create a competitive business advantage. As emerging technologies continue to evolve, engineering is poised for a transformative future. Emerging technologies have driven innovation and progress in today's rapidly evolving digital landscape. The collective impact of emerging technologies such as artificial intelligence, machine learning, cloud computing, big data, and the Internet of things is undeniably transformative.

EMERGING TECHNOLOGIES IN PHARMACEUTICAL

The pharmaceutical industry is a complex and dynamic field, constantly evolving to meet the demands of patients worldwide. It is facing a multitude of industry-specific and global trends. Each of these global trends represents significant challenges in and of itself. These global trends have six major implications for pharma: rising operational complexity, increasing risk, shifting capability requirements, higher capital expenditure requirements, variable-cost increases, and opportunities for savings. Now is the time to rethink operational strategy to respond to these trends and remain competitive [5]. Figure 1 shows some emerging technologies in pharmaceutical industry [6]. These include the following [7,8]:

- *Generative AI*: Artificial intelligence (AI), also known as machine intelligence, could revolutionize the pharmaceutical sector. It has been improving the pharmaceutical industry for some years now, and the advent of generative AI will transform the stages of drug development, driving efficiency, clinical trials, and safety through automation, optimization, and advanced information. Other applications of AI within big pharma include disease target identification, in silico high throughput screening, formulation development, clinical trial management, and dosage error reduction. AI is redefining many aspects of pharma, including drug discovery, clinical trials or even supply chain optimization. The application of generative artificial intelligence for the discovery and design of novel biologics holds substantial potential for the biopharmaceutical industry, although practical implementations are still limited.
- *Robotics*: Every company today is in search of a way to bring in robots to the company like the pharma factory in a bid to shave off some costs and obtain many results within the shortest time possible. Robots reduce variations and variations mainly in dosage and quality in the production line. They are perfect for aseptic zones needed in

production of vaccines and other biologics. New generations of robots to the industrial environment have integrated sensors and real-time learning, so they can update from current methods. Figure 2 shows the use of robots in industry [9].

- *The Internet of Medical Things (IoMT):* IoT is one of the most widely deployed technologies in many industries, and the pharmaceutical sector will be able to benefit greatly from IoMT through the combination of mobile applications and IoT devices.
- *Big Data & Analytics:* Data is one of the most powerful assets for achieving significant breakthroughs in the discovery and development of new drugs, as well as new applications for existing compounds. The pharma industry requires high-performance systems to analyze the large volumes of data generated during the drug discovery and development process. Artificial intelligence analyses data much faster than humans, so it can be used to pick out the important parts of research projects, analyze them, and generate new insights. Big data can help determine a drug's side effects beforehand, which reduces the time needed for clinical trials. The costs of research and development inflate the cost of medications, so shortening R&D cycles can help lower the costs of medication for patients. Big data analytics can help create more effective drugs and make scientific discoveries in pharmacology. It offers an opportunity to develop personalized medicines by studying genomic data. Big data analytics and the IoT help companies anticipate and shape future customer demands, bringing greater efficiencies to the distribution of final goods. While pharmaceutical companies keep collecting more data, they want to use it more thoughtfully and make use of the analytical tools.
- *Blockchain:* Blockchain is a decentralized digital ledger that records and verifies transactions, making it highly secure and resistant to tampering. Blockchain technology is very important for the pharmaceutical industry in its various stages of drug production and distribution and can modernize the industry by introducing three key elements: privacy, transparency, and traceability. It enhances data integrity and traceability within the pharmaceutical industry by recording transactions and information in a highly secure and transparent manner. This technology has different applications across various sectors in the pharmaceutical industry, including clinical trials, regulatory compliance, personalized medicine, and supply chain innovation. A significant benefit of blockchain in pharmaceuticals is its ability to improve supply chain management. There is another use case approach where blockchain has a lot to say in the industry: tracking counterfeit or substandard medicines that can be very harmful to people.
- *Biotechnology:* Biotechnology systems open up a new paradigm for understanding the interrelationships between networks of biological processes. They are based on a technical procedure that allows data to be evaluated on a much larger scale and completely changes the way biological and biotechnological research is conducted.
- *Precision Medicine:* Precision medicine, treating each patient as a unique individual, is advancing with omic and data analysis. It offers personalized treatment plans, improving efficacy and patient satisfaction. Precision medicine stems from the concept of tailoring treatment to the distinct characteristics of each patient. Precision medicine offers a new approach to disease diagnosis, treatment, and prevention. This technology uses the patient's genes and lifestyle to help doctors make accurate, data-backed decisions. While precision medicine is still at the early development stages, offering truly customized treatment to patients will require a total overhaul of how healthcare professionals deliver and develop therapies. Drug exposure models play a crucial role in precision medicine by assessing the pharmacokinetic and pharmacodynamic attributes of drugs. The demand for precision medicine is driving pharmaceutical companies to revolutionize their production techniques.
- *3D Printing:* 3D printing is a form of additive manufacturing in which computer-aided design software is used to generate a digital model and a 3D object is printed from raw materials in either liquid or particle form. Within the pharmaceutical sector, 3D printing finds utility in the realms of drug formulation, organ fabrication, and regenerative therapy. Consequently, 3D printing enables the crafting of medical formulations tailored to individual age or physiological profiles, as well as the creation of precision dosage pills. Bioprinters are pivotal in advancing the fields of bioinks, tissue scaffolding, and microfluidics. Additive manufacturing is revolutionizing pharmaceutical production, enabling the development of age-dependent

medical formulations. Figure 3 shows a typical 3D printer [9].

- **Bioprinting:** Bioprinting uses 3D printing-like techniques to create imitations of natural human tissue and organs. This technology combines cells, growth factors, and other biomaterials to form a mesh-like structure. These 3D-printed organs can replace live human subjects during clinical trials. This incredible technology forms micro-organs and tissues that react the same way the human body does to new drugs and substances.
- **Wearables:** Many wearables are already being used to remotely monitor heart rate, blood pressure, or glucose levels, and as their use increases, better treatments and monitoring can be prescribed and monitored from anywhere. Wearable tech integration allows pharma companies to do more than just manufacture, market, and sell drugs. The technology gives patients greater power to manage their conditions and make critical decisions. Figure 4 shows a typical wearable [10].
- **Cloud Computing:** This has been one of the most significant advances in the virtual industrial world. It allows analysts to extract and analyze huge quantities of information (i.e., big data) from the supply chain, products, machines, and production lines. Cloud technology is a steady trend for businesses in various industries. In the pharmaceutical field, this innovation allows for more efficient work. It provides the opportunity for data analysis, increased information security, and scaling ability, which allows you to store a huge amount of patient data.
- **Extended Reality:** Mixed reality (MR), virtual reality (VR), and augmented reality (AR) are transforming visualizations in unparalleled ways. Extended reality (XR) technologies, including virtual reality (VR) and augmented reality (AR), are enhancing visualization in pharmaceutical research and manufacturing. Pharma startups are investigating the potential of extended reality technologies in the realms of pharmaceutical research and manufacturing. AR refers to the integration of artificial information within reality by overlaying digital data onto physical objects or spaces to improve the user experience and enable tasks to be executed more efficiently. Typically, this involves the use of superimposed imaging, video- or computer-generated simulations, which are projected on a smartphone or tablet. AR is one of the most promising tools for improving technical manuals in the context of Industry 4.0.

AR manuals can present the technical information registered to the object in the real workspace with potential benefits that increase with more complex operations.

BENEFITS

There are interesting advantages of implementing emerging technologies in pharma. A healthy pharma sector produces positive outcomes for both patients and investors. Digital tools, robots, and sensors are becoming cheaper and easier to access, and they can be used to capture all manner of raw data. Emerging technologies are creating great opportunity within the pharmaceutical field, promising to facilitate the development and delivery of medicines in a highly streamlined, efficacious, and innovative manner. The latest technologies, like AR/VR, artificial intelligence (AI), and additive manufacturing, help pharma companies accelerate the research and development process, create personalized products, and conduct testing in innovative ways. Other benefits include the following [11]:

- **Decision-making:** Big data analytics enable data-driven decisions in many areas, like drug development, clinical trials, and quality assessment. With the advent of big data and analytics, data-driven decision-making is set to become the norm rather than the exception in the pharmaceutical industry.
- **Cost Reduction:** Following the previous point, making data-driven decisions also has a direct impact on cost reduction consequently.
- **Customization:** Manufacturing has shifted from mass production to mass customization. Intrinsically linked with 3D printing and additive manufacturing is the field of personalized treatments. The move from mass production to mass customization is underpinned by digital workflows. Customized dosage forms are a key benefit of 3D printing in pharmaceuticals. With 3D printing, pharmaceutical companies can create personalized dosage forms tailored to an individual patient's unique needs, such as customized shapes, sizes, and dosages.
- **Personalized Medicine:** The era of one-size-fits-all medication is gradually giving way to personalized medicine. This trend towards more tailored therapies promises better patient outcomes and is set to redefine the future of pharmaceutical manufacturing.
- **Flexible Production:** The pharma industry is adapting its manufacturing to meet new market needs, like producing smaller batches for precision medicine.

- *Operational Efficiency:* A low-code platform can automate repetitive tasks, reduce errors, and enhance productivity. It can streamline various aspects of pharmaceutical operations, from managing supply chains to optimizing workflows.
- *Automation:* Automation in the management of the pharma industry can be described as the implementation of technologies within companies which makes different tasks with minimal interference from human personnel. It is a proven technique that incorporates computer control in production processes to achieve more precision. Automation machinery has become more important over the years, due to its ability to efficiently handle manufacturing, packaging and distribution challenges. Advanced technology is improving automation machinery as an integration tool in the pharmaceutical industry.
- *Remain Competitive:* The integration of emerging technologies into the pharmaceutical industry allows companies to remain competitive. It applies to both internal and external competition. For example, the latest technology in the pharmaceutical industry allows businesses to compete with large companies like Apple.
- *Counterfeiting Issue:* Emerging technologies in the pharmaceutical sector can help combat counterfeiting. Any patient can use digital technology to verify the authenticity of medications, for example, by scanning the barcode on the packaging.
- *Transparency:* This has always been an extremely important factor in the pharmaceutical industry. Transparency refers to the sharing of information. The data results that come from research and development can be extremely valuable, providing insights for various parties. This was seen during the pandemic when information was shared regarding vaccines.

CHALLENGES

Despite its potential to change the pharmaceutical world, integrating emerging technologies comes with challenges, ranging from data security to acceptance within the healthcare sector. The adoption of emerging technologies in the pharmaceutical industry poses regulatory, security, and financial challenges. Intellectual property and valuable data in the wrong hands could mean years of research going down the drain. Other challenges include the following [11]:

- *Initial Costs:* Modern tools and instruments involve high costs of acquisition and installation.
- *Regulations:* The pharmaceutical industry is one of the or rather the most heavily regulated in the

world and successfully managing complex rules and regulations is a major issue facing them. Pharmaceutical companies operate within a wide range of regulations and standards. Technology acts as both a guiding light and a shield, ensuring that organizations remain compliant with evolving requirements. Regulatory automation and compliance technologies can streamline processes, reduce errors, and improve the timeliness of approvals. To succeed, everyone in the industry needs to be able to adapt rapidly to any potential changing regulations.

- *Security:* As pharmaceutical companies shift towards increased digitization, so too does their risk of data security increase. The biggest challenges arise from data storage and management, especially as the Internet of things and big data use continues to grow. Data privacy and security are crucial, given the reliance on digital solutions and the handling of sensitive information. Protecting sensitive data and intellectual property from cyber threats is a continuous concern.
- *Talent Shortages:* The pharma industry is facing talent shortages linked to wider labor market trends, including the 20 percent increase in demand for STEM-related roles across the life sciences industry in the United States. The current pool of pharma digital talent is at least 14 percent lower than demand, and many companies are finding it challenging to recruit technical talent.
- *Cybersecurity:* The pharma industry is a prime target for cyberattacks. With the innovation and massive investment in R&D and intellectual property on patient health data, the sector is a hot spot in the data threat landscape. Cybersecurity threats are one of their biggest concerns of pharmaceutical companies. Data breaches affect the company's valuation and erode the trust customers, and patients have in the institution. In addition, companies that fall victim to cybercriminals face hefty fines and overall company disruption.
- *Sustainability:* The call for greener practices and sustainable supply chains is growing louder across all sectors, and the pharmaceutical industry is no exception. The journey towards sustainability is now a necessary voyage for manufacturers across the globe.
- *Interoperability:* This is the seamless sharing of data between different systems. It is set to become a prime focus. The aim is to create an integrated, collaborative ecosystem that fosters productivity and efficiency

CONCLUSION

The pharmaceutical industry has been traditionally slow to embrace new technology. Embracing emerging technologies is crucial for staying competitive in the industry. Pharma operations leaders now have an opportunity to deliver even greater value to their organizations by achieving this shift in focus, but they must act quickly to keep abreast of the challenges confronting the industry.

In the pharmaceutical industry, staying at the forefront of technological trends is a must. Incorporating emerging pharma technologies while ensuring regulatory compliance and prioritizing patient care, will be key in defining the industry leaders of the future. More information about emerging technologies in the pharmaceutical industry can be found in the books [12,123].

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Figure 1 Emerging technologies in pharmaceutical industry [6].



Figure 2 Use of robots in industry [9].



Figure 3 A typical 3D printer [9].



Figure 4 A typical wearable [10].

